Workshop on Detectors for Synchrotron Research

Spectroscopy Working Group

Peter Siddons

Summary

This group is arguably the most diverse of the working groups established by the Workshop. It covers a wide spectral region, and hence several detector technologies are needed. In addition, the subject of photoelectron detection and energy analysis is an integral part of any low energy spectroscopy program.

In spite of this diversity there were common themes which emerged from our discussions. In general there was a strong need for greater throughput with enhanced energy resolution. All participants were restricted in their scientific capabilities by either or both of these parameters. A common theme was the isolation of a small signal from a large background. In this case, the background signal rate dominates the measurement time, not the desired signal. It is often the case that the background consists of photons of slightly different energy than the desired signal, and hence enhanced energy resolution is an important aspect of the challenge to isolate the signal of interest.

It is important to emphasize that the throughput issue is not simply one of speed and convenience. There are many situations where the concentration of the active species in the sample is so low that high quality measurements could take several days, during which time the sample is degrading under the incident radiation load. One might cite samples of biological origin, or those requiring ultra-clean surfaces. In such circumstances, the measurements become impractical using current detector technology, although quite feasible in terms of source capability.

Similarly with the need for better energy resolution. Current commercial devices offer photon energy resolutions of around 100-200eV in the range of photon energies from 500eV to, say, 20keV. It is a common experience to have a sample containing a strong concentration of an element differing only slightly in its emission line spectrum from the element of interest. In such a circumstance, the only solution presently available is to employ some kind of diffraction-based spectrometer to analyze the emmisiion spectrum. Such devices are notoriously inefficient, and again the measurments quickly become impracticable.

It became clear that the throughput issue is strongly limiting even at the first generation facilities. This problem is obviously a long-standing one. Compared to the resources devoted to developing enhanced sources, a negligible resource has been available for detector improvements. This is in strong contrast to the field of High Energy Physics where similar resources are typically consumed by detector and machine efforts. It is clear that all current sources outperform their detector systems by factors in the range one hundred to one million simply in terms of available count rate. Experimenters routinely throw away photons in order that the detector can operate in its linear regime. This inefficiency is made worse if one also considers the collection efficiency (i.e. the fraction of total scattering collected) of current detection systems.

It also became clear that we cannot rely entirely on market-driven developments to satisfy our needs, since the total synchrotron market is not of industrial scope. It may be appropriate to involve industry in replication efforts for designs developed as part of a research program, but in general the size of the market does not commercially justify the expense of such research development by industry. All of the currently available commercial detector systems are outgrowths of basic R&D performed by academics from Universities and National Laboratories. This follows directly from the preceding considerations of development costs vs. market volume.

The group discussed the current state-of-the-art in a range of technologies. It was obvious that many experimenters did not have access even to the current level of commercially available detector systems, and an obvious first step to enhance the efficacy of the investment in beamlines and machines would be to simply purchase the current level of technology for as many beamlines as possible. In most cases, gains of at least one order of magnitude could be made. We strongly recommend that this course of action be vigorously pursued.

We went on to discuss emergent technologies, i.e. those which could become available in the near (~5year) future. There are clearly areas of development by other scientific communities from which we could benefit in this time frame. Obvious areas are HEP and Astronomy (e.g. NASA). Indeed, the current wave of CCD-based detectors for crystallography is based on technology from the astronomy field. The large event rates seen by HEP experiments have clear parallels to the SR experiments, and some (in particular European) groups are beginning to capitalize on their developments in the custom microcircuit area. Detector arrays of millions of elements are becoming the norm for HEP, whereas in the SR field, 30 is considered large. Nevertheless, it will be essential for us to develop specialized circuits suited better to our needs if we hope to benefit from the HEP experience in high data rate systems. It will not be enough just to take what exists and try to apply it in the SR field. An obvious area, which will need attention, is that of noise performance. The energy deposited in a HEP detector element is typically 100keV or so, and usually only a binary result is needed, i.e. presence or absence of an event. In contrast, we need to resolve the energy of the photon at the 100eV level. Thus, not only must the noise performance be enhanced, but the quantity of data per event increases for SR experiments

Almost all of the large-scale detector systems discussed were based on silicon as the sensing element. Due to its rather low Z, silicon (in thicknesses suitable for array fabrication using conventional semiconductor processes) becomes quite inefficient at energies much above 15keV. The only currently viable alternative is germanium, and it suffers from the serious disadvantage of requiring cryogenic operation. There is a real need for a wide-gap high-Z semiconductor material which could enable large arrays with good efficiency and energy resolution at higher energies. Current efforts seem to be concentrated on compound semiconductors such as CdZnTe and GaAs. Results to date are still rather disappointing from our perspective, although both are making progress.

Detectors with enhanced energy resolution are beginning to appear. We discussed the new detectors based on superconducting technology which are reaching a useable level of development. These systems provide improvements of between 10 and 100 in resolution, but currently do not have the rate capabilities of the semiconductor detectors. Nevertheless, there are clear applications for such devices at SR facilities, and there was strong interest shown by the group. Arrays of these devices are now being developed which may soon aleviate the count rate restrictions and open up more potential areas of application. One possible way to extend the use of these detectors might be to use them in conjunction with moderate resolution diffractive pre-filters such as multilayer or mosaic-crystal analyzers. In this way the analyzer can be made reasonably efficient, and much of the contaminating flux removed.